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Growth and food habits of carp, Cyprinus carpio L., in Clear Lake, Iowa

Mochamad Ichsan Effendie
Iowa State University

GROWTH AND FOOD HABITS OF CARP, CYPRINUS CARPIO L.,

IN CLEAR LAKE, IOWA

by

Mochamad Ichsan Effendie

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INTRODUCTION

Since carp in Clear Lake are undesirable fish, the Iowa State Conservation Commission regularly removes this species from the lake to prevent these fish from becoming abundant. In 1945, Bailey and Harrison reported that carp did not appear to be abundant enough to interfere with game fish production. Parson (1950) intimated a direct relationship between the carp population and the decrease of the aquatic vegetation of the lake and the decrease of the yellow perch population.

English (1951) reported on growth rates of carp collected in Clear Lake in 1950 but nothing has been published on their growth in the lake since that time. The growth rate as reported by English was shown to be fast compared to growth in several other waters (Walburg and Nelson, 1966). Students collecting fishery data for the Iowa Cooperative Fishery Research Unit noted that there were many young of the year of carp in Clear Lake in 1966. It was therefore suggested that a study of carp at this time would be desirable. Field collections for this study were therefore started in June, 1967. The author was at Clear Lake collecting data, June 8 to August 28, 1967, and August 5 to September 3, 1968.

Although the first critical use of scales for determining age and growth of fish was with carp, by C. Hoffbauer in 1894 (Van Oosten, 1929), the scales of carp are not easily interpreted (Frey, 1942; English, 1951; McConnell, 1951; Youn, 1962). Opercles and vertebrae have also been used to determine the age and growth of carp (McConnell, 1951; English, 1951; Sigler, 1958; Youn, 1962). Comparison of the three techniques were made for many of the fish collected in 1968. Some observations were also made on the food habits and digestion rates.

DESCRIPTION OF STUDY AREA

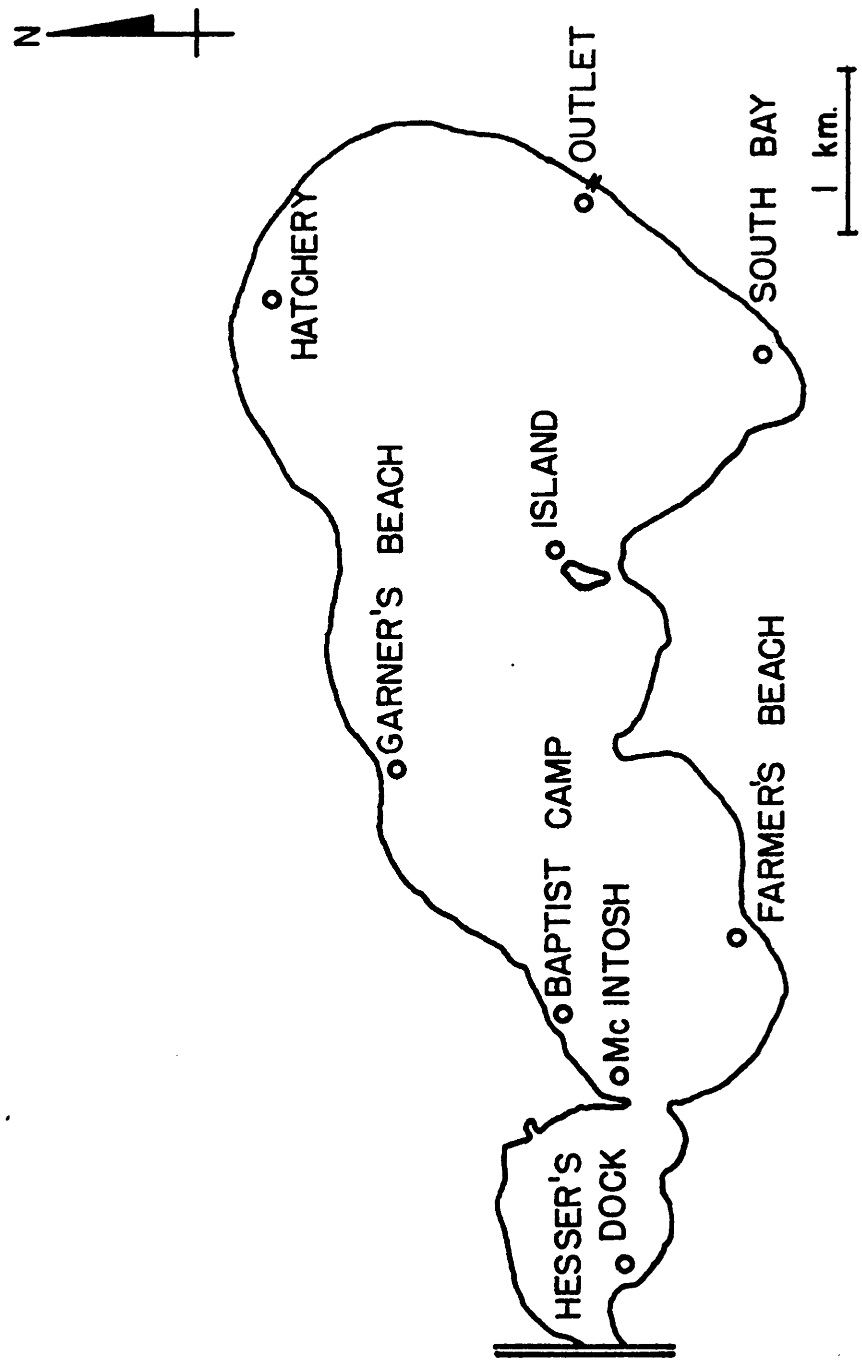
Clear Lake is an eutrophic lake located in Cerro Gordo County, north central Iowa. It has an area of 1,474 hectares (3,643 acres) and its length is approximately 7.5 kilometers with a width of 3 kilometers. Bailey and Harrison (1945) presented the history of the lake, its limnological and morphological features and described the fish population of the lake. More detailed information on limnological features of Clear Lake have been reported by Pearcy (1953).

The lake is divided into two main areas, the eastern and western, by a sand bar extending from McIntosh Wood State Park to Lone Tree Point. There is no major inlet into the lake and the outlet is located on the south shore of the eastern part of the lake.

For the purpose of this study, eight stations were chosen along the shore and one station near the Island (Fig. 1). Insofar as possible, these nine gillnetting stations were selected as the best representative sites of the lake without interfering with people fishing, swimming, boating and skiing. In the eastern part of the lake the stations on the north shore were Hatchery, Garner Beach, Baptist Camp and McIntosh, and on the south shore were Farmer's Beach, South Bay and the Outlet. The Island was the only station in the open water portion of the lake. It was about 100 meters from the main south shore. Hesser's Dock station was on the western part of the lake.

All stations used in this study except the Island station were between 20 and 30 meters from the shore with depth ranging from 2 to 3 meters. In addition to these stations, carp were also captured with an electric shocker in bulrush areas across from the Hesser's Dock station.

Figure 1. Map of Clear Lake, Iowa, showing the location of gillnetting stations


N
HATCHERY
OUTLET
SOUTH BAY
1 km.
GARNER'S BEACH
ISLAND
FARMER'S BEACH
BAPTIST CAMP
Mc INTOSH
HESSER'S DOCK

MATERIALS AND METHODS

For the purpose of this study, 437 and 157 carp were collected during the summer of 1967 and 1968 respectively. An electric shocker and seines were used to supplement the gill net catch. Gill netting was conducted each week for 24-hour periods at each station. Four gill net were fished during the day from 6:00 a.m. to 6:00 p.m. and two nets were fished at night from 6:00 p.m. to 6:00 a.m. Each net was 125 feet long and consisted of five 25-foot sections, each with a different mesh size: 3/4, 1, 1-1/4, 1-1/2, and 2 (bar measure in inches). The nets were fished for 2 out of each 4 hours during the 24-hour period.

Total lengths, weights, and scale samples were obtained in the field. Scales were taken from the left side of the body of carp, three rows above the lateral line and in front of the dorsal fin.

In the summer of 1968, all fish caught either by gill nets or seines were brought to the hatchery laboratory to obtain the data. After the total lengths, weights and scale samples were obtained, the opercle on both sides were removed following the method described by English (1951). Both opercles were dipped directly into a boiling water for one to three minutes while the flesh was still fresh. The flesh and tissue were then easy to remove by washing the opercles under the running tap water. The opercles were dried and cleaned with paper towel and then placed in the properly-marked scale envelope.

Vertebrae were removed from just behind the Weberian apparatus to just under the anterior part of the dorsal fin. These vertebrae were dipped directly into a boiling water for one to three minutes, and cleaned under the running tap water. Also the blood vessel and nerve were removed. The dry vertebrae were placed in the same scale envelope for further examination.

Scale preparation and reading were done with the method as described by Smith (1954) and Vanderpuye (1968). One to three scales from each fish were pressed into unheated plastic slides by a roller press. The impression of the scale on the plastic strip was projected with a micro-projector with a magnification of 26-1/2 times. The clearest image was selected for reading. Manila tagboard strip was used to measure the distances from the centrum of the scale to each annulus and to the front part of the scale by adding marks on it with pencil. A nomograph was used to calculate the growth, as described by Carlander and Smith (1944).

Measurement of the radius of opercle followed the method described by McConnell (1951) and English (1951) from the posterior part of the fulcrum to the most distant point of the curved edge of the opercle. A conventional divider or caliper was used for this purpose. Distances of each measurement were transferred to a millimeter scale.

Vertebrae were examined under a binocular microscope. No measurement or calculation was made.

In the food habits study, the intestine from the esophagus to the rectum of 186 carp collected in the summer of 1967 were preserved in a ten percent solution of formaldehyde. The food contents were measured by air-drying for about five minutes and determining water displacement in a 12-cc centrifuge tube. To analyze the food items, the gut contents were diluted with water up to ten times. Two or three cc of the well-mixed solution was placed on a watch glass and examined under a binocular. To estimate the volume percentage of the items, separate piles were made of each type of item. To estimate the volume percentage of algae and microcrustaceans, one or two drops of the well-mixed solution were placed on a glass slide and examined under a microscope.

In the studies on the digestion rates, 20 fish were sacrificed at each of the three time periods: at capture, and 6 and 12 hours after confinement. The length of the food contents in the intestine was measured in millimeters and the volume was measured in cubic centimeters.

GROWTH

The Scale Method

When the scale impressions were first examined, there were many marks that were interpreted as annuli or year marks. These rings had features often mentioned as criteria for recognizing annuli: crowding of the circuli, anastomosis of circuli in the posterior-lateral fields, and irregular formation of circuli.

On the basis of these rings, the carp collected in 1967 were mostly ages 3 to 7. However it had been pointed out that there had been many young carp in 1966 and that therefore there should be many age 1 carp in 1967. Furthermore, tabulation of length frequencies (Table 1) showed that most of the carp in the 1967 sample were similar in size and made one large mode, suggesting that they were of one age group. Their size increased from June to August, demonstrating rapid growth. Furthermore the size in June was about what might be expected for the 1966 year class carp, based upon their sizes in 1966 as reported in the July - September 1966 Quarterly Report of the Iowa Cooperative Fishery Unit (page 16):

Date	Number	Total length in mm Mean	Range
July 13	15	50	22 - 86
July 20	36	87	31 -127
July 27	120	110	48 -137
Aug. 3 - 17	165	121	31 -165
Aug. 24 - Sept. 9	53	176	60 -239

After recognizing that most of the 1967 carp were age 1 and the 1968 carp were age 2, it was possible to more definitely define the characteristics of the annuli.

Table 1. Size distribution of carp by 30 mm group collected from Clear Lake in 1967 and 1968

	1967			1968		
Length	June	July	August	July	August	September
150-179	1					
180-209	4					
210-239	25	1				
240-269	12	10				
270-299	19	85	8			
300-329	4	111	55			
330-359	1	29	49			
360-389			7	4	16	2
390-419				18	36	8
420-449				11	32	6
450-479				1	5	1
480-509					3	
510-539						
540-569		1			1	
570-599	1	1			3	
600-629	1	1	1		2	
630-659						
660-689						
690-719					1	

Criteria for Carp Annuli

The structure and appearance of the scales of bony fishes, either ctenoid or cycloid type, differ among the species. Cycloid scales of carp seem to fulfill the criteria proposed by Berg and Grimaldi (1967). The circuli appearing on the surface of the scales as a thin dark concentric lines surrounding the centrum on both shoulder and anterior field. The formation of the circuli was uniform during early growth. These circuli continue with the same thickness and spacing. At a distance from the centrum the thickness and space change but there is no anastomosis in the shoulder field. This zone probably is an indication of the changing of the food habits from planktonic to benthic forms. Nikolsky (1963) designated this zone as the fry or larval zone. In the zone after the larval zone the number of radii increased and some of them do not extend beyond the first annulus. Before the true annulus was formed the thickness of the circuli increased on both shoulder and anterior fields. The spaces between the circuli became narrower.

At the time the annulus was formed, the circuli at the shoulder fields became irregular in thickness and some anastomosed. On the anterior field some of the radii stopped and did not continue to the beginning of the next annual zone. The next annual zone began with a wide space after the irregularity in thickness of the circuli. This wide space was followed by widely spaced broken circuli. The circuli on both shoulder fields were not broken. These circuli with wide spaces indicate that the growth was fast at that time. These in turn were followed by thick and regular circuli. Also on this place new radii were formed.

The second annulus was similar with the first one, where the thickness of the circuli increased, the space between them decreased. The circuli on both shoulder fields were irregular and anastomosed.

In a segment of the anterior field designated by two radii starting from the centrum and extending to the edge of the scale, the number of radii which stopped at the second annulus were usually bigger than at the first one.

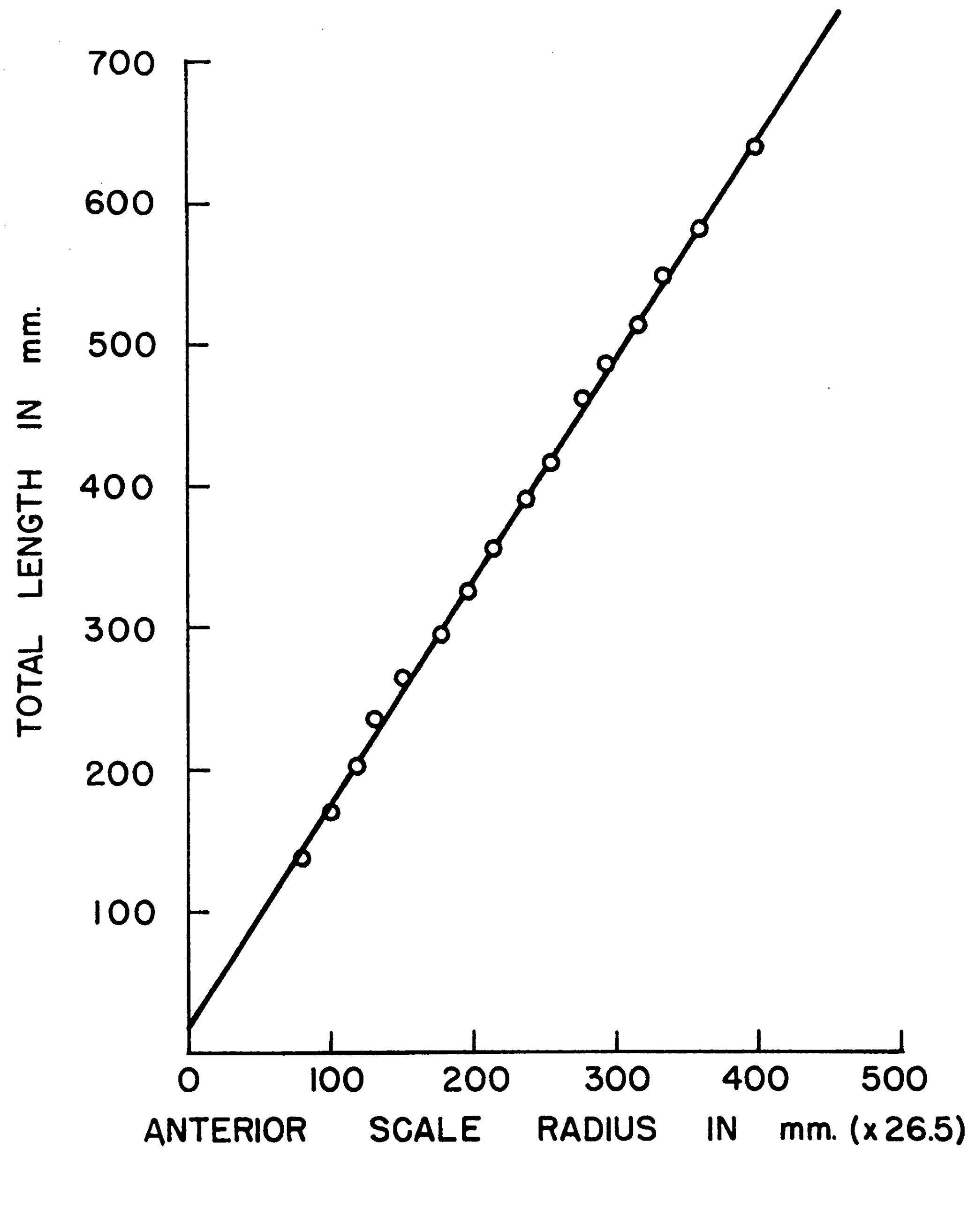
The circuli on the third and older annual zone were different from the first and the second one. In these annual zones the thickness of the circuli were almost similar. The third and older annuli were indicated by a dense ring of circuli in the anterior field and irregular circuli and anatomosis in the shoulder fields. These situations were followed by a wide space at the beginning of the following annual zone. The number of the radii did not usually increase at the third and older annuli.

False annuli can be recognized as follows: the circuli increased in thickness in anterior field but there were no irregularities and no anastomosis on both shoulder fields. There were no wide spaces between the thick and the thin circuli.

Body-scale Relationship

Since the amount of the scale cover on carp is constant or nearly so, increase in length of the body is associated with increase in size of the scale. The nature of the relationship between the length of the body and the anterior radius of the scale affects the calculation of the past growth. With 106 carp from the two collections, the mean total length (L) for each 10-millimeter group was plotted against the mean radius (R) of the scale, (Figure 2). The equation fit by the least

Figure 2. Body-scale relationship based on 106 carp from 1967 and 1968 collection ($L = 22.7$ mm. $+ 1.568 R$)


TOTAL LENGTH IN mm.
700
600
500
400
300
200
100
0
100
200
300
400
500
ANTERIOR SCALE RADIUS IN mm. (x 26.5)

squares method is as follows:

$$L = 22.7 \text{ mm} + 1.568\ R$$

Growth calculations on nomograph were based on 23 mm rather than zero (Carlander and Smith, 1944). McCrimmon (1968) and McCrimmon and Swee (1967) reported that the scale formation of carp was not complete on any fish of less than 22 mm.

Growth As Determined from Scales

Scales were examined from all of the larger carp, but only from a portion of the carp from the abundant size groups.

The 1967 collection consisted of two age groups, one and three, and was dominated by one-year-old fish. The annulus was just forming on the scales of one fish collected in June.

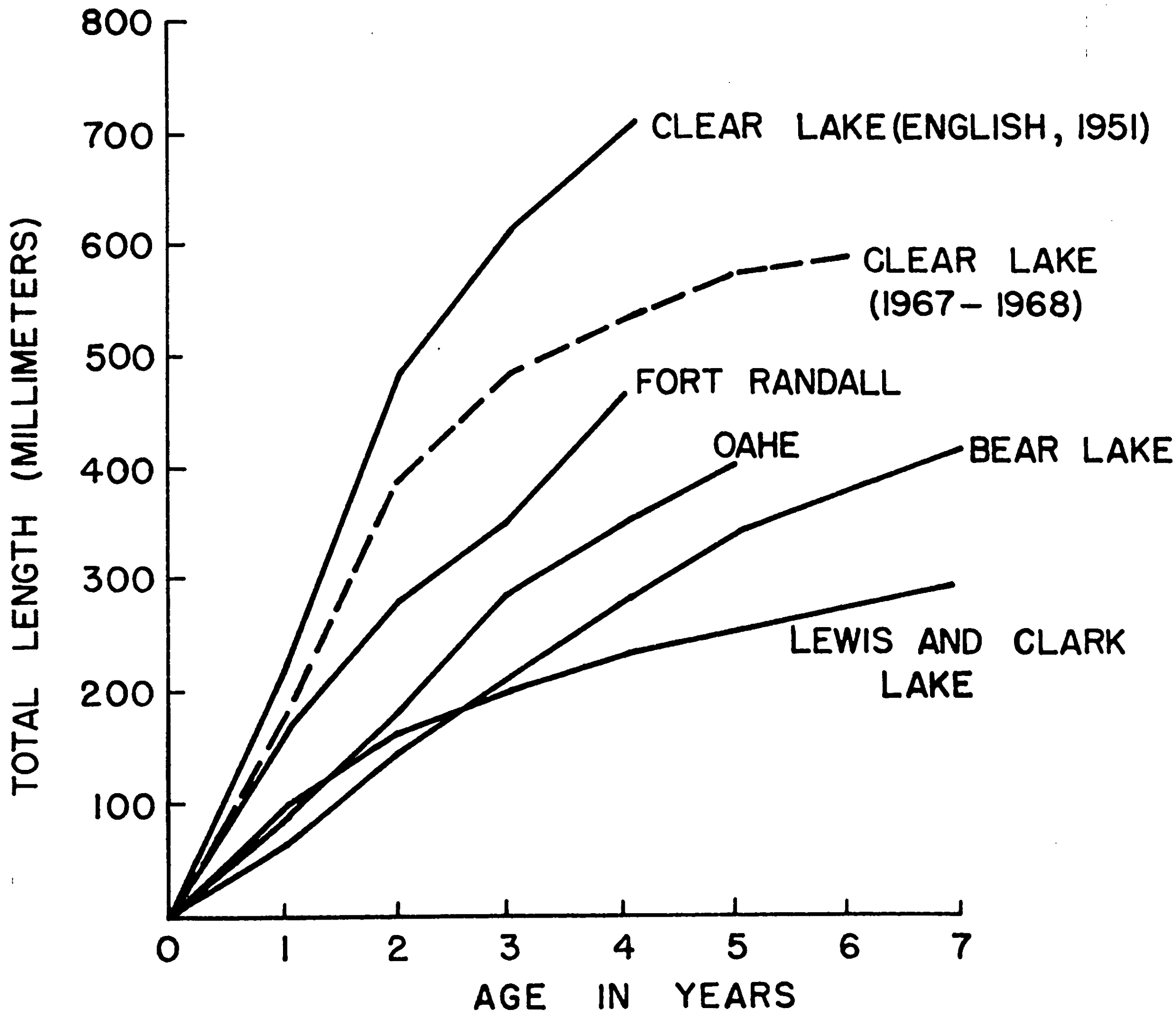
The two-year-old group dominated the 1968 collection, but there were no one, three, four and seven-year age groups. The 1966 year class carp were dominant in both 1967 and 1968. The fish increased in length most in the second year and the average increments in the later years of the life were small (Table 2). The eight-year-old fish appeared to be a slow-growing individual.

Walburg and Nelson (1966) made a comparison of the growth of carp from several lakes and reservoirs. Carp from Clear Lake were the fastest of all. However carp from the same lake in 1967 and 1968 were growing slower than in 1951 (Figure 3). This evidence indicated possibly the condition of the lake and its fish population was less suitable for carp in 1968 than in 1951.

Table 2. Average calculated total lengths in each age group (scale method) of Clear Lake carp, 1967 and 1968

Age group	No. examined	Average calculated length at each annulus 1	2	3	4	5	6	7	8	TL at capture
1 9 6 7										
I	35	213								288
II	-	-	-							-
III	6	157	414	536						592
Average	41	205	414	536						
Annual Increment		205	257	122						
1 9 6 8										
I	-	-								
II	58	203	353							420
III	-	-	-	-						-
IV	-	-	-	-	-					-
V	3	182	424	508	545	581				600
VI	3	123	335	418	535	577	591			608
VII	-	-	-	-	-	-	-	-		-
VIII	1	205	419	468	517	535	550	565	582	590
Average	65	198	356	464	537	573	581	565	582	
Annual increment		198	158	79	73	36	14	15	17	
Combined average	106	201	361	498	537	573	581	565	582	
Annual increment		201	166	99	73	36	14	15	17	

Figure 3. Calculated length at end of each year of life of carp from Clear Lake, Fort Randall Reservoir, Oahe Reservoir, Bear Lake and Lewis and Clark Lake (Walburg and Nelson, 1966) and from Clear Lake 1967 and 1968


800
700
600
500
400
300
200
100
TOTAL LENGTH (MILLIMETERS)
0
1
2
3
4
5
6
7
AGE IN YEARS
CLEAR LAKE (ENGLISH, 1951)
CLEAR LAKE (1967- 1968)
FORT RANDALL
OAHE
BEAR LAKE
LEWIS AND CLARK LAKE

The Opercle Method

Although age determination from the annuli of the scale has become a standard method in fishery research, rings on other skeletal structures such as from opercle, vertebrae and spines have also been used for this purpose. Sneed (1950) and Kuyon (1965) reported some difficulties in interpreting rings on spines of channel catfish. The application of the opercle method to calculate the past growth of perch was done by Le Cren (1947) and on carp by English (1951) and McConnell (1951). There are many advantages to the use of the opercle method for carp, because the year marks generally can be seen easily without additional optical instrument. A year mark of the opercle can be seen better in a darkened room by placing the opercle on a fluorescent lamp which is covered by a white glass. I had greater confidence in interpretation of age from the opercle than from scales or vertebrae. Using the opercle method required much less time than scale or other bone methods. However some difficulties were encountered in determining the age of older fish because the rings were obscure due to the thickness of the bones.

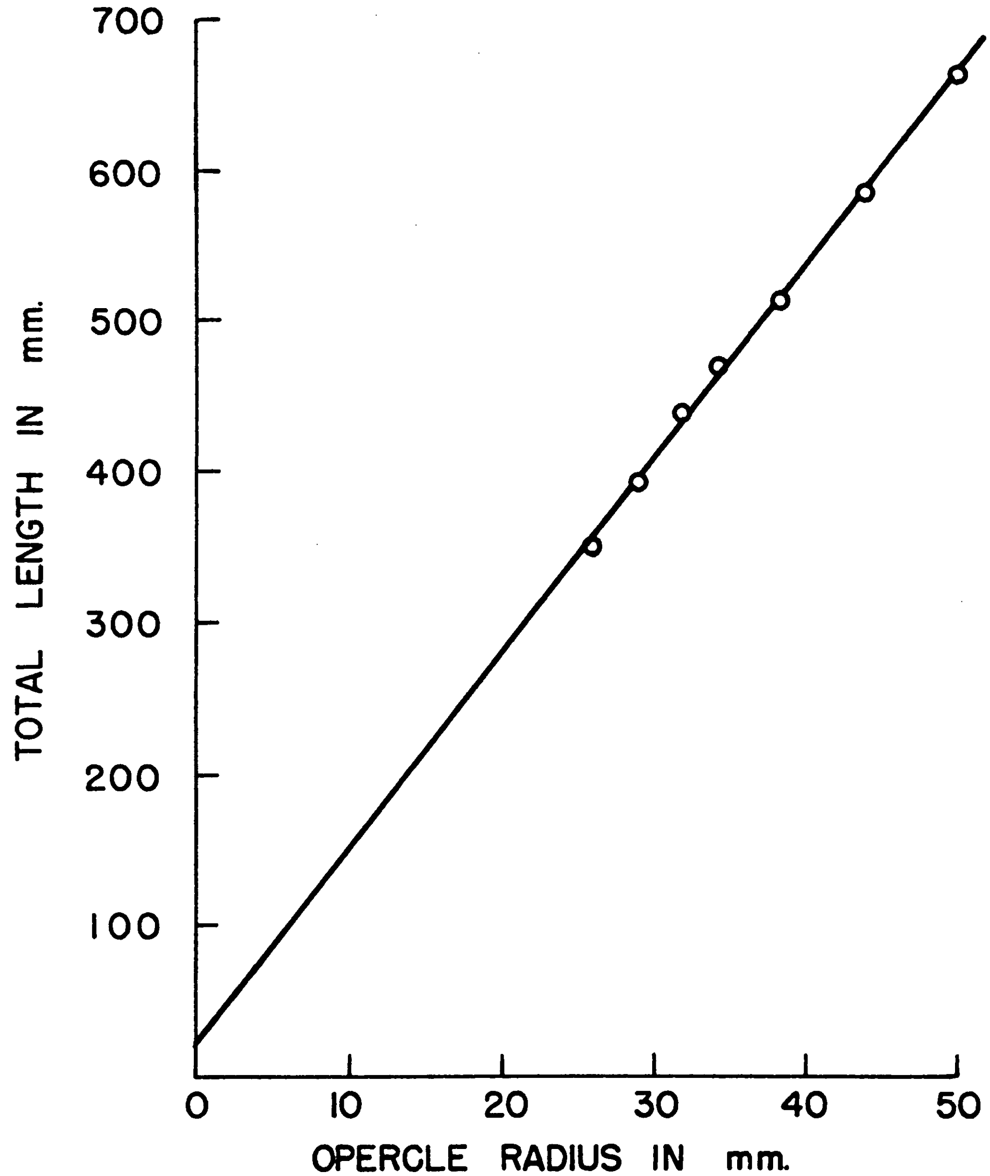
Body-opercle Relationship

Determination of body-opercle relationship was done with the same method as to determine the body-scale relationship. The mean total length of the fish for each 10-millimeters group was plotted against the mean radius of the opercle from the fulcrum to the most distant point (Figure 4). Analysis was based on 120 carp of the 1968 collection and gave an equation as follows:

$$L = 20.5 \text{ mm.} + 12.928\ R$$

The growth calculations by opercle method were based on this equation.

Figure 4. Body-opercle radius relationship based on 120 carp from 1968 collection ($L = 20.5$ mm. $+ 12.928\ R$)


700
600
500
400
300
200
100
TOTAL LENGTH IN mm.
0
10
20
30
40
50
OPERCLE RADIUS IN mm.

The growth calculation by using the opercle method (Table 3) showed that higher results were obtained than by using the scale method. It seemed that the development of the opercle was fast within the first year and it was not proportional to the growth of the body. Further study of the development of opercle in relation to the increment of the body is suggested.

There was one opercle which did not agree either with annuli of the scale or with year marks of the vertebrae. This fish, which had been aged by the scale method as five years old, was four years old by the opercle method. But the vertebrae rings of this fish showed it was five years old (Figures 5, 6, 7).

Table 3. Average calculated lengths in each group (opercle method) of Clear Lake carp, 1968

Age group	No. examined	Average calculated length at each year mark 1	2	3	4	5	6	7	8	TL at capture
I	-	-								-
II	58	244	356							420
III	-	-	-	-						-
IV	1	316	422	544	583					610
V	2	272	450	511	546	581				595
VI	3	326	424	493	534	563	590			608
VII	-	-	-	-	-	-	-	-		-
VIII	1	343	430	480	517	532	546	566	575	590
Average	65	251	364	504	542	564	579	566	575	
Annual increment		251	113	72	38	29	25	20	9	

Figure 5. Scales of carp from 1968 collection with 2 (August 22, L = 379 mm., W = 709 grams), 5 (July 22, L = 610 mm., W = 2863 grams) and 6 annuli (August 28, L = 700 mm., W = 3912 grams). The vertebrae and opercle of the same fish are shown on the following figures

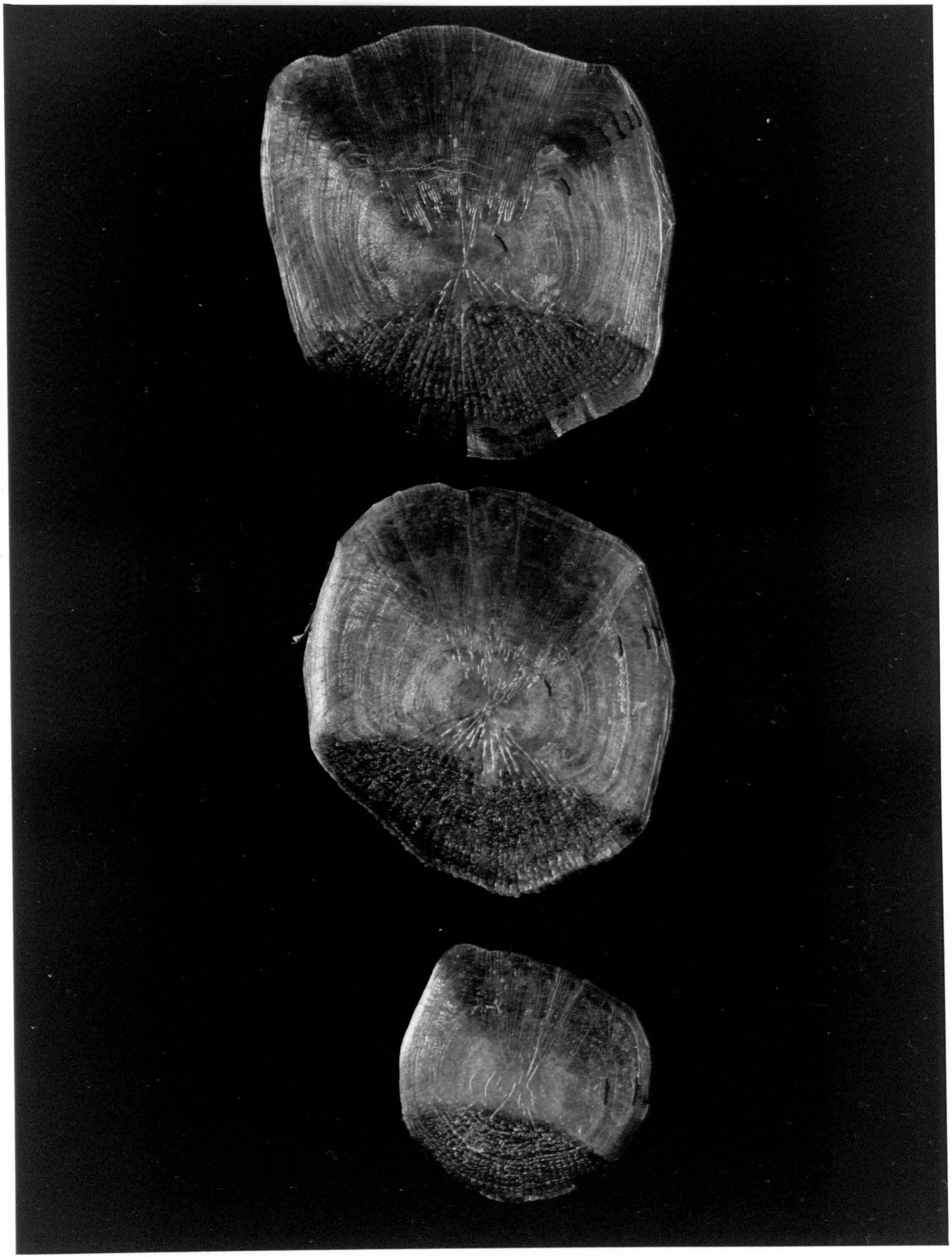


Figure 6. Vertebrae of the same fish as Figure 5 showing 2, 5, and 6 year marks

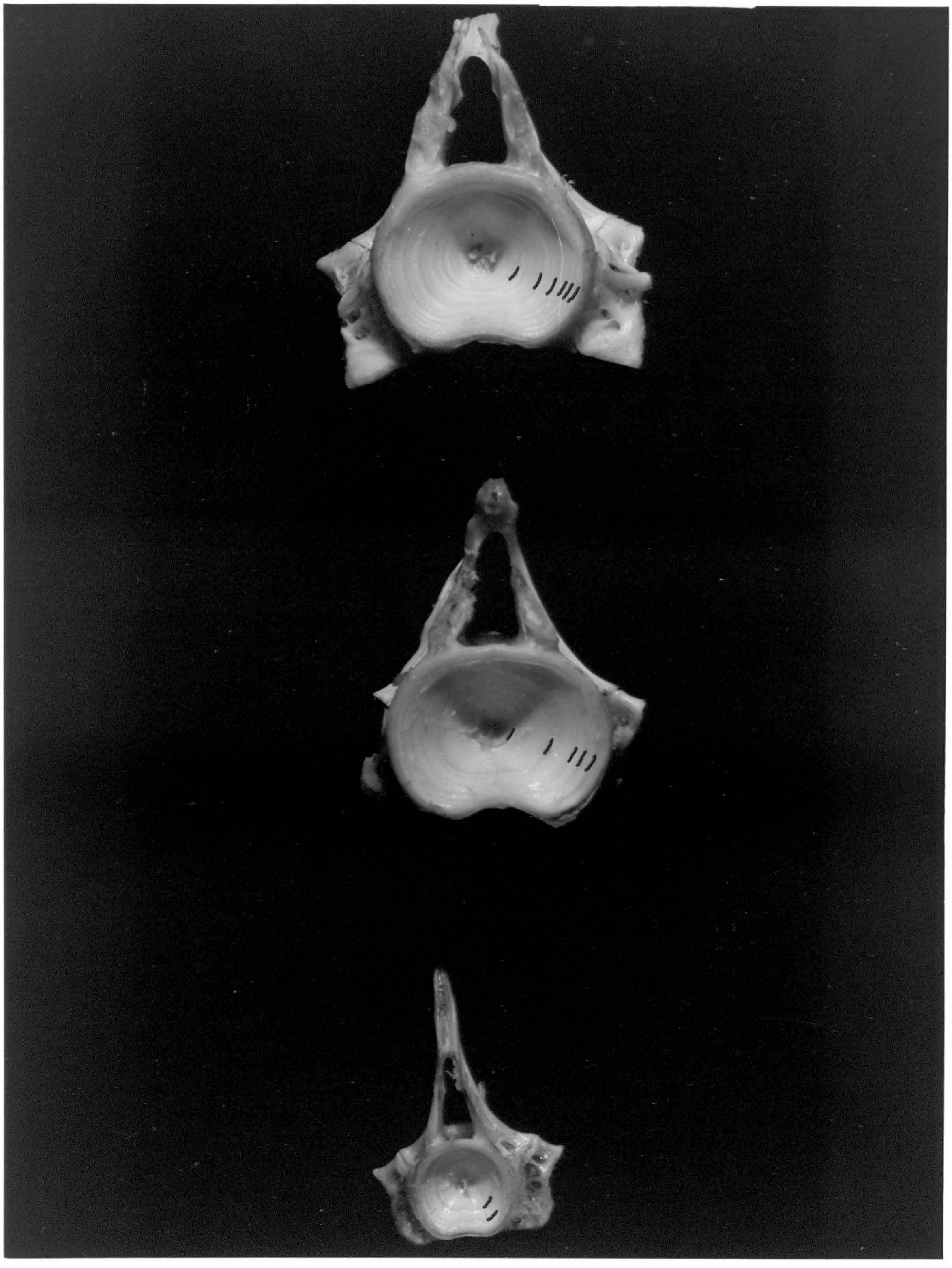
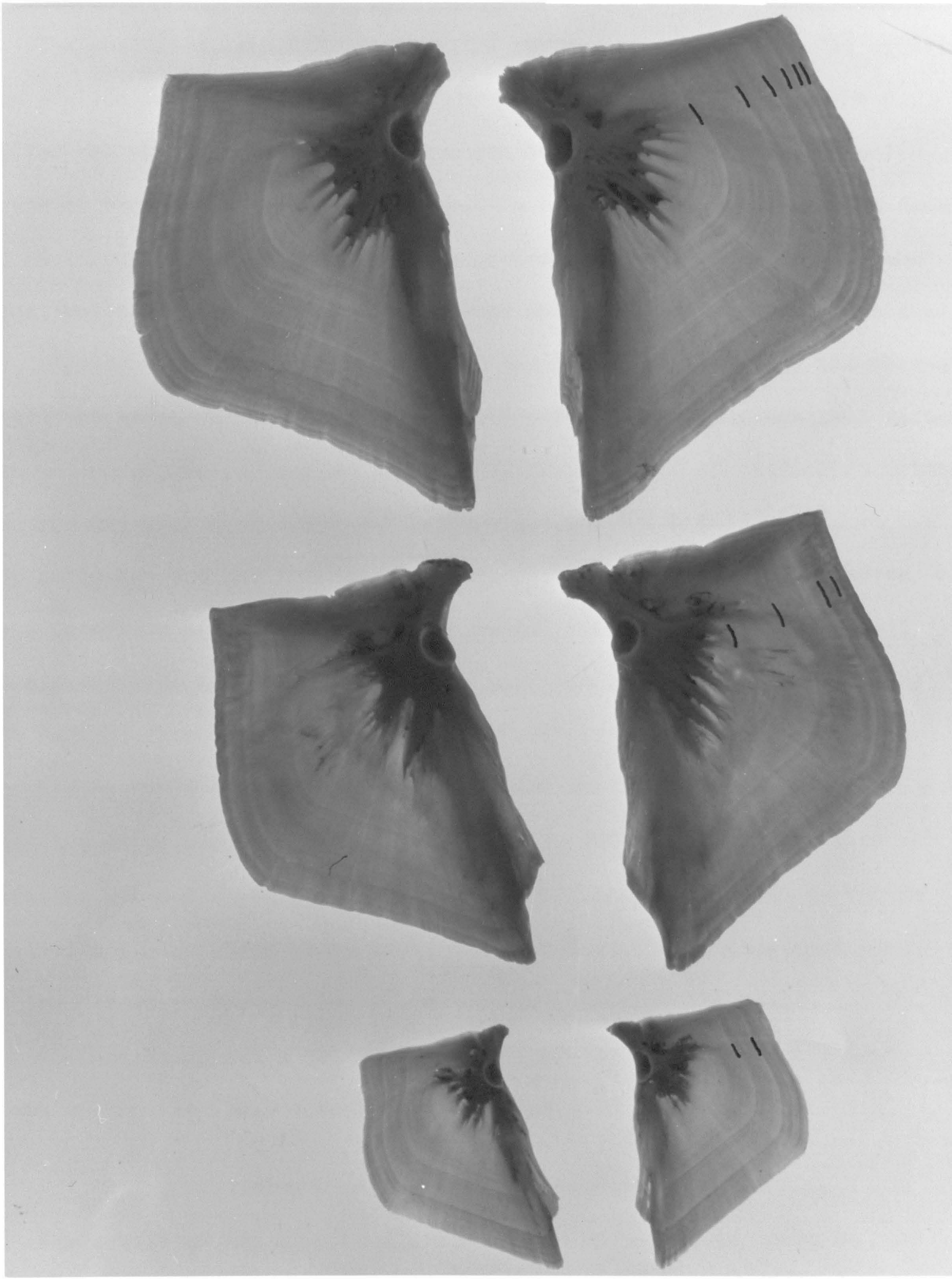


Figure 7. Opercle of the same fish as Figure 5 showing 2, 4, and 6 year marks



The Vertebrae Method

The vertebrae method in determining age and growth of fish has usually been applied to the scaleless fish. However, Lewis (1949) before he applied the vertebrae method to the black bullhead, attempted the application of the method to scaled fishes. He found that ages determined from the vertebrae method were as accurate as from the scale method. In some cases, bullhead vertebrae had extra rings which did not correspond to the age. Appelget and Smith (1951) applied the vertebrae method to the channel catfish by using various methods of sectioning to see the rings, but direct observation of the rings from the centrum proved to be an applicable method.

The dry method as suggested by Appelget and Smith was applied to the carp vertebrae and the results were better than examining wet vertebrae. The alternation of the white and dark bands is clear and even the small light white band within the wide white band can easily be detected. The dark band has been suggested by previous authors as the year mark. The narrow dark bands usually were raised on the surface of the vertebrae above the white bands. The tissue on the dry vertebrae can easily be discarded without damaging the surface of the centrum. If the vertebrae is still wet, the white small bands are almost similar to the dark ones and the tissue on the surface of the centrum obscures the rings.

In this study I did not make any calculations to compute the past growth of the fish by the vertebrae method.

Validity of Annulus as a Year Mark

The scales of the fish at the age up to two years old could be read without difficulty after the annuli were redescribed. The corresponding year marks were also clear on the opercle and vertebrae. Most of the scales, vertebrae and opercle bones of the same fish that were examined side by side showed the same age. The right and left opercle which were symmetrical showed a consistent indication of the same age of the same fish. All vertebrae taken in this study had the same rings on both sides.

The data and observation of the present study showed that the carp collection of 1967 was dominated by fish whose scales each had one annulus. The collection of 1968 was dominated by fish with scales having two annuli. The increment of annuli from one to two in the samples taken from the 1967 and 1968 collection indicated that one annulus was formed in one year. There was a correlation between calculated length of the fish and the number of annuli. Generally fish taken in late summer had wider margins outside of the annuli than those taken in June, indicating that during the fast growth period the annulus was not formed (Table 4), and that the annulus was formed prior to the season's growth.

Frey (1942) found that the formation of the annuli was different in one, two and three-year-old carp. The small carp of the same sex and age formed the second and the third annuli earlier than the larger one. Female carp of the same size and age formed the second and the third annuli earlier than the males.

This evidence of the study at Clear Lake indicated that the validity of the annuli on scales and year marks of opercle and vertebrae can be accepted.

Table 4. Average growth increment in millimeters since the last annulus of Clear Lake carp by age and time of capture in 1967 and 1968

1 9 6 7

	Age I		Age III	
	No.	increment	No.	increment
June	15	36	2	47
July	8	85	3	51
August	12	122	1	86

1 9 6 8

	Age II		Age V		Age VI		Age VII	
	No.	increment	No.	increment	No.	increment	No.	increment
July	10	59	1	23	-	-	-	-
August	42	67	2	16	3	17	1	8
September	6	76	-	-	-	-	-	-

LENGTH-WEIGHT RELATIONSHIP AND CONDITION

The general formula: $W = cL^n$ (Hile, 1936) has been used to express the relationship between length and weight of fish, where W is weight, L is length and c and n are constants. On transformation of weight and length into logarithms the equation is linear: $\log W = \log c + n \log L$.

The length-weight relationships were expressed by the equations:

$$1967 \qquad \log W = -3.6728 + 2.5479 \log L$$

$$1968 \qquad \log W = -4.2274 + 2.7546 \log L$$

where in both cases the b value was different from 3.0 (t for 1967 = 30.76 and t for 1968 = 8.61, both of which are significant at the 95% level). Since the slopes were smaller than 3.0, carp become lighter for their length as they grow larger.

From these equations calculated weights were determined and also a comparison was made of the average actual weight with the calculated weights of 1967 and 1968 (Table 5). Analysis of covariance (Table 6) demonstrated that the length-weight regression slopes of the 1967 and 1968 collection differ, even at the 1 percent level. Since the regression coefficients differ the test of adjusted means is not meaningful.

The coefficient of condition to express the relative plumpness or "general well being" of carp from Clear Lake in 1967 and 1968 was computed using the formula

$$K(TL) = \frac{W\ 10^5}{L^3}$$

where W = weight in grams, and L = total length in millimeters.

The average of K(TL) of Clear Lake carp taken in 1967 was 1.63 (437 fish) and in 1968 was 1.36 (157 fish) (Table 5). It would therefore appear that the younger carp of Clear Lake were fuller bodied in 1967 than the next year. However the condition of carp in 1968 was similar to that reported in Clear Lake for 1947 to 1950. English (1951) found that the coefficient of the condition of carp in Clear Lake was 1.33, and there were no trends due to sexual difference.

Table 5. Length-weight relationships of carp from Clear Lake

Average TL in mm.	No. fish	Average weight in grams observed	computed	K(TL) average
	1 9 6 7 (Log W = -3.728 + 2.5479 log L)			
158	1	50	85	1.27
190	2	112	138	1.63
209	6	166	174	1.82
229	22	224	219	1.87
251	15	282	275	1.78
275	75	363	345	1.75
302	133	447	447	1.62
331	153	550	562	1.52
363	24	631	708	1.32
524	6	2,512	2,291	1.75
			Total average	1.63
	1 9 6 8 (Log W = -4.2274 + 2.7546 log L)			
331	1	537	513	1.48
347	1	617	589	1.48
363	6	724	661	1.51
380	15	759	759	1.38
398	37	871	851	1.38
417	41	933	977	1.28
437	32	1,096	1,096	1.31
457	12	1,318	1,259	1.38
479	3	1,549	1,413	1.41
501	1	1,622	1,622	1.29
550	1	2,138	2,089	1.29
575	2	2,455	2,344	1.29
603	4	2,818	2,692	1.29
692	1	3,715	3,890	1.29
			Total average	1.36

Table 6. Analysis of covariance and test of significance of the hypothesis that the regression coefficient is the same in collections of 1967 and 1968

Source of variation	d.f.	Sums of squares and products Sx^2	Sxy	Sy^2
Between	1	2.3288	5.7372	14.1321
Within	592	2.0376	4.2592	15.6186
Total	593	4.3664	9.9964	29.7507

Source of variation	Error of estimate Sums of squares	d.f.	Mean squares
Total	6.8650	592	--
Within	6.7156	591	0.01136
Test of adjusted means	0.1494	1	0.1494
Deviation for individual means	2.0338	590	0.00345
Difference between regression	4.6818	1	4.6818

F test for regression: 4.6818/0.00345 = 135.704 **

F test for adjusted means: 0.1494/0.01136 = 13.151 **

** Significant at one percent.

FOOD HABITS

Alimentary Canal of Carp

The alimentary canal of fish can be divided into two regions, the "Kopfdarm" comprising the buccal cavity and pharynx and the "Rumpfdarm" comprising the fore-gut (esophagus and stomach), mid-gut (intestine) and hind-gut (rectum) (Barrington, 1957). The digestive tract of carp follows that fundamental division with some exceptions and shows the simple form among the teleosts. The anterior part of the buccal cavity is bounded by protrusible lips and the floor contains a rudimentary tongue (Curry, 1939). The buccal cavity is lined with a stratified epithelium and provided with mucous cells and taste buds. The latter are concerned in control and selection of food. There is no dentition at the margin of the mouth or on the palate. The dentition of carp is composed of three pairs of pharyngeal teeth which are especially associated with the branchial arches. These function as a grinding mill to convert hard substances such as insect larvae, snails, seeds and aquatic vegetation into small bits.

The carp esophagus is a short muscular tube connecting the pharynx with the front part of the intestine. The pneumatic duct from the air bladder enters the esophagus dorsally. The musculature of the esophagus is striated and provided with taste buds, a feature which aids in the swallowing and rejection of food (Curry, 1939). Where the esophagus enters the peritoneal cavity, the tract enlarges suddenly to form the intestine. The wall of the anterior portion of the intestine is thicker than that of the posterior portion. There is no pocketing or holding area.

The enlargement of this area is often mistaken for a stomach, but the entrance of the bile and pancreatic duct just behind the esophagus suggests that carp have no stomach.

The intestine is coiled in three loops, laying one inside the other, ventral to the swim bladder, median and ventral to the gonads. Pancreatic tissue fills each double loop of intestine and small diffuse strands of this tissue are found following the loops. Usually the length of the intestine is almost twice that of the body.

The acidity of fish which have true stomachs is due to hydrochloric acid, and the pH values range from 2.4 to 7.6 with a mean of 5.6. But according to Al-Hussaini (cited by Barrington, 1957) the pH reading of Cyprinus intestine has a range between 6.12 and 7.72 and the reaction of the intestine is usually alkaline. The gall bladder bile of Cyprinus has a pH between 6.8 and 7.2.

Analysis of Food Items

In this study, intestine contents of 186 carp were grouped by location and time of capture (Table 7). Major groups of food items were aquatic insects, microcrustaceans, mollusks, algae and aquatic plants. Because pharyngeal teeth of carp act as grinding mills, many food items cannot be determined and these are grouped as undetermined plant and digested material. All major groups of food items were found in carp intestines from all stations except that mollusks were not found in carp taken from Ventura, Island and Baptist Camp.

Aquatic insects identified in the food were Chironomus sp., Leptocella sp., Mystacides sp. and Caenis sp. . Generally chironomid

Table 7. Food of carp from Clear Lake, 1967, expressed as percentage of total volume and frequency of occurrence on each date of collection (T = trace)

Date of collection	June 8		June 21		June 23		June 26		June 28	
Station	Ventura		Island		Ventura		Farmer		Outlet	
No. of stomachs taken	35		3		14		3		7	
Percent of stomach containing food	94		100		85		100		28	
Total volume of food (in cc.)	111.7		7.4		103.5		17.9		8.5	
Weight mean (in gr.)	224		434		424		432		396	
Range	50-393		230-680		204-2213		397-487		324-500	
	Percent		Percent		Percent		Percent		Percent	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Insects										
<u>Chironomus</u> sp.	14.5	100	31	100	4.6	83	10	100	9	100
<u>Palpomyia</u> sp.							T	33		
<u>Leptocella</u> sp.	T	3			.2	25				
<u>Mystacides</u> sp.	.1	57	.3	33	3.7	83	1.6	33	10	50
<u>Caenis</u> sp.					1.8	25			.5	50
Water mites										
Hydracarina	T	27			T	16				
Crustacea										
<u>Daphnia</u> sp.	T	3	2.6	33						
<u>Bosmina</u> sp.	.1	45	5	33	.4	50	.3	33	T	50
<u>Cyclops</u> sp.	T	30			.5	41			.5	50
<u>Gammarus</u> sp.					.1	25				
Seed shrimp	.3	75			.6	75	T	67	.5	50
Mollusks										
<u>Gyraulus</u> sp.							.6	33	.8	50
<u>Valvata</u> sp.									.8	50
<u>Pisidium</u> sp.					.1	6	2.7	67		
Rotatoria										
<u>Keratella</u> sp.										
<u>Brachionus</u> sp.										
Algae										
<u>Ulothrix</u> sp.	.1	97	.2	100	.2	100	.2	100	.1	100
<u>Zygnema</u> sp.	.1	93	.2	100	.2	100	.2	100	.1	100
<u>Straurastrum</u> sp.	T	3			T	6	T	33		

July 6 South Bay		July 11 Outlet		July 14 Garner		July 17 Hesser's Dock		July 31 Baptist Camp		August 2 Island	
19		15		18		15		16		11	
74		53		89		67		100		100	
103.6		34.9		171.4		51.8		144.8		173.8	
434 348-567		435 270-566		509 406-595		426 314-510		505 390-622		816 495-3175	
Percent		Percent		Percent		Percent		Percent		Percent	
Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
37	100	7.8	100	16	100	5.4	90	6.9	100	8.8	100
						T	20	T	6		
7.5	71	20	100	11	69	8.5	50	.7	69	.4	36
T	7	2	44	T	12	.3	30	.2	24	.3	27
T	14			T	6	.2	20				
T	21	T	22			2.2	80	1.4	19	T	9
.1	28	.4	66	.7	56	2.7	60	1.4	50	T	9
.1	35	1.1	66	.4	69	2.1	80	T	12	T	27
.1	7	.2	55	.2	38			.1	12	T	18
.1	59	.3	55	T	50	.6	60	T	69	T	45
.4	7	.7	33	.1	19					T	9
.4	7	.1	11	.1	19						
.8	14	.6	55	.3	50	.3	10				
				T	12	T	10				
.2	100	T	88	.2	100	.1	80	.2	93	.2	100
.2	93	T	77	.2	100	.1	80	.2	93	.1	84
				T	6			T	6	T	15

Table 7. (Continued)

Date of collection	June 8		June 21		June 23		June 26		June 28	
Station	Ventura		Island		Ventura		Farmer		Outlet	
No. of stomachs taken	35		3		14		3		7	
Percent of stomach containing food	94		100		85		100		28	
Total volume of food (in cc.)	111.7		7.4		103.5		17.9		85	
Weight mean (in gr.)	224		434		424		432		396	
Range	50-393		230-680		204-2213		397-487		324-500	
	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.
Algae (continued)										
Pediastrum sp.	T	81	T	100	.1	100	T	100	T	100
Scenedesmus sp.					T	12				
Cosmarium sp.					T	41	T	33		
Closterium sp.										
Tylopella sp.					4.1	6				
Oscillatoria sp.	T	33			T	58	T	67	T	50
Anabaena sp.			T	33						
Microcystis sp.	T	45	T	67	T	50	T	33	T	50
Diatoms										
Fragillaria sp.					T	12				
Navicula sp.	T	39			T	75	.1	100	T	100
Cyclotella sp.	T	54	T	33	.1	75	.1	100	T	100
Cymatopleura sp.	T	57	T	67	T	50	T	33		
Plant										
Potamogeton sp.	T	9			2	16				
Plant seed	T	12			.5	41				
Undet. plant material	1	90	.3	67	22	91	14	67	3	100
Other										
Sand	T	12	.3	33	13	50	1	67	.5	100
Undet. dig. material	82.3	100	59	100	57	100	70	100	73	100

July 6 South Bay		July 11 Outlet		July 14 Garner		July 17 Hesser's Dock		July 31 Baptist Camp		August 2 Island	
19		15		18		15		16		11	
74		53		89		67		100		100	
103.6		34.9		171.4		51.8		144.8		173.8	
434 348-567		435 270-566		509 406-595		426 314-510		505 390-622		816 495-3175	
Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.	Percent Vol.	Occ.
T	85	T	77	T	88	T	50	T	93	T	69
T	28	T	11	T	19	T	40	T	12	T	23
T	28	T	11	T	6	T	30	T	6		
.3	7	3.3	22	.2	12	8	10			6.1	7
T	71			T	56	T	40	T	69	T	7
						T	10				
T	57	T	44	T	44	T	40	T	43	T	53
T	21	T	11	T	31						
T	42	T	44	T	68	T	40	T	25	T	15
T	78	T	77	T	100	T	70	T	62	T	37
T	21	T	11	T	43	T	10	T	43	T	15
		.5	33	T	6	11	10	.4	37	11	61
T	14	1.1	11	.1	6	3.6	80	1.4	25	72	77
.6	50	5.6	77	5.3	75	3.1	80	1.8	93	14.3	77
6.7	71	3.3	66	2.7	50	.3	10	1.5	62	.1	31
41	100	51.5	100	61.3	100	61.3	100	83	100	45	100

larvae and pupae were the animal items in the diet. They were found in most carp intestines and their occurrence ranged from 83 to 100 percent on each date of collection. The highest percentage of volume of chironomid was 60 found in a carp taken from South Bay station on July 6, 1967. Caddisfly larvae (Mystacides sp.) were next important among aquatic insects. They were found in all stations and their occurrence ranged from 33 to 100 percent. The highest volume percentage of caddisfly larvae was 70 found in a carp taken from Ventura Station on August 6, 1967. These larvae were taken by carp together with their cases which are composed of sand. Although each case was not examined, there were many empty cases and possibly some cases were taken without their larval inhabitants. Most sand found in the intestine may come from caddisfly larvae cases but some is undoubtedly incidentally taken from the bottom. Considerable amounts of sand were found in intestines of carp and the percentage of occurrence ranged from 10 to 100.

Mayfly nymph (Caenis sp.), caddisfly larvae (Leptocella sp.) and chironomid (Palpomyia sp.) were taken by carp in varying amounts in a few individual fish. Palpomyia was only found in one fish.

Water mites (Hydracarina) were taken by carp incidentally and the occurrence ranged from 14 to 20 percent. They usually were only in trace volumes.

Microcrustaceans found in carp intestine were Daphnia sp., Bosmina sp., Cyclops sp., Gammarus sp. and ostracods (seed shrimp). Gammarus sp. never reached 1 percent of the food volume. Very often Daphnia sp. Bosmina sp. and Cyclops sp. were found together, and Daphnia sp. made 8 percent and Bosmina sp. 15 percent of the food in a carp taken from

Island station on June 6, 1967. The volume of a combination of Daphnia sp., Bosmina sp. and Cyclops sp. was 30 percent in a carp taken from Hesser's dock station.

The third major group of animal items utilized by carp was mollusks which was composed of three species as follows: Gyraulus sp. (snail), Valvata sp. (snail) and Pisidium sp. (fingernail clam). Most of the shells of these animals were found in small fragments due to the action of pharyngeal teeth. However, some of these small Pisidium were unbroken. Only 10 percent of the total fish observed utilized mollusks and the volume ranged from a trace to 20 percent. One fish taken from South Bay station of July 6, 1967, utilized mollusks in a combination of these three species up to 60 percent of the volume of the food items.

In addition to these three major group of animals, Rotatoria (Keratella sp. and Brachionus sp.) were found in carp intestines taken from stations Garner, Hesser's dock and Island. They were usually infrequent and apparently incidental to regular feeding.

Algae in carp intestine were 15 species as follows:

Blue Green Algae:	Oscillatoria sp., Anabaena sp. and Microcystis sp.
Green Algae:	Ulothrix sp., Zygnema sp., Straurastrum sp., Pediastrum sp., Scenedesmus sp., Cosmarium sp., Closterium sp. and Tylopella sp.
Diatom:	Fragillaria sp., Navicula sp., Cyclotella sp. and Cymatopleura sp.

Although many species of algae might be found in a carp intestine, the volume in each individual did not exceed 1 percent, except that Tylopella sp. constituted 80 percent of the volume in a carp taken from

Ventura on June 23, 1967 and 50 percent in one from Hesser's dock on July 17, 1967. Among the green algae *Ulothrix* sp. and *Zygnema* sp. were dominant and the percentage of occurrence ranged from 80 to 100 on each date of collection. *Pediastrum* was the next after *Ulothrix* and *Zygnema* either from the standpoint of occurrence or volume.

Among diatoms only *Navicula* sp. and *Cyclotella* sp. were found in most carp intestines. Like other algae their volume never exceeded 1 percent and their percentage of occurrence ranged from 15 to 100. Only in one station I did not find *Navicula* in carp intestines.

In the overall picture, algae were not important from the standpoint of volume. However, from the standpoint of occurrence, algae were apparently taken by carp without selection.

Only *Potamogeton* was recognized among the higher plant material but the percentage of volume did not exceed 13, and the percentage of occurrence ranged from 9 to 80. *Potamogeton* usually occurred together with plant seeds and other plant material in the carp intestine. Plant seeds probably cannot be separated from other bottom materials by carp. The volume percentage of plant seed ranged from trace to 7.2. The undetermined plant material was treated separately from other undetermined digested material because plant material still can be recognized and easily be separated. Occurrence of undetermined plant material ranged from 50 to 100 percent. Digested material which could not be determined ranged from 40 to 83 percent of the volume and occurrence was 100 percent.

Conceivably carp compete with bullheads because food of adults of both species are predominantly chironomid larvae (Forney, 1955).

Digestion Rates

Measurements of digestion rates were made in a manner similar to that described by Moen (1953). On two evenings, August 4 and 11, 1967, 30 carp, between 315 and 736 grams, were collected at 8:00 p.m. Each evening 10 carp were examined immediately, 10 after 6 hours and 10 after 12 hours of confinement without food. They were maintained in water at 68° F. The percent with food, average volume of food in the intestine and average length of intestine with food decreased with each 6-hour period (Table 8). At 12 hours most of the food had been digested or passed out of the intestine. The items in the intestine after 12 hours were mostly hard and difficult to digest (Table 9).

Table 8. Measurement on intestinal contents at capture and after 6 and 12 hours of confinement (20 carp at each period)

Capture Time	Percent with food	Mean volume of food	Mean length of food	Percent of intestine with food
8:00 p.m.	65	2.75 cc.	590	37
2:00 a.m.	55	1.01 cc.	566	20
8:00 a.m.	25	0.22 cc.	573	7

Food Habits of Carp in Different Habitats

Food and feeding habits relationships of fish are usually closely related to their ecological habitat. We may compare the food habits of carp from lakes, ponds, rivers and reservoirs.

Moen (1953) found that the food of carp from 14 northwestern Iowa

Table 9. Food of carp from Clear Lake, 1967, expressed as percent of total volume and frequency of occurrence at capture, and after 6 and 12 hours of confinement

Time of sacrifice	8:00 p.m.		2:00 a.m.		8:00 a.m.	
No. of intestine taken	20		20		20	
No. of intestine containing food	13		11		5	
Total volume of food in cc.	55.0		26.5		4.4	
Mean weight of fish in grams	452		462		489	
Range	337-736		315-560		337-736	
	Percent		Percent		Percent	
	Vol.	Occ.	Vol.	Occ.	Vol.	Occ.
Insects						
Chironomus sp. (larvae and pupae)	3.5	92	4.5	100	6.6	60
Leptocella sp.	T	7	T	9		
Mystacides sp.	6.1	77	27.8	91	25.9	80
Caenis sp.	2.2	46	3.3	36		
Hydracarina						
Water mites	T	15	T	9		
Crustacea						
Bosmina sp.	T	15				
Cyclops sp.	T	38	T	45		
Gammarus sp.	T	38	T	18		
Seed shrimp	T	54	T	36		
Rotatoria						
Keratella sp.	T	7	T	9		
Brachionus sp.	T	7				
Algae						
Ulothrix sp.	T	92	T	91	T	60
Zygnema sp.	T	85	T	82	T	60
Straurastrum sp.	T	15	T	9	T	20
Pediastrum sp.	T	70	T	45	T	20
Scenedesmus sp.			T	27	T	20
Cosmarium sp.	T	7				
Tylopella sp.	6.3	15	T	9		
Oscillatoria sp.			T	18	T	20
Anabaena sp.	T	7				
Microcystis sp.	T	62	T	45		
Dactylococopsis sp.	T	15				

Table 9. (Continued)

	Percent Vol.	Percent Occ.	Percent Vol.	Percent Occ.	Percent Vol.	Percent Occ.
Diatom						
Navicula sp.	T	46	T	27	T	20
Cyclotella sp.	T	38	T	27	T	20
Cymatopleura sp.	T	15	T	27		
Plant						
Potamogeton sp.	6.3	54	10.6	54	3.2	40
Plant seed	1.3	54	7.9	73	17.0	100
Undet. plant mat.	13.4	69	8.4	91	10.0	100
Other						
Sand	0.9	46	T	45	0.7	40
Undet. digested mat.	52.6	100	32.2	100	35.0	100

lakes was predominantly animal material. During the summer periods, aquatic insects, small crustaceans and snails made up the bulk of the food. In lakes having poor bottom fauna, high amounts of debris occurred in carp intestine. Fragments of plants seldom made up more than 10 percent and aquatic seeds less than 2 percent of the food of carp. During winter periods the food items eaten by carp were crustaceans and dipterous larvae. Plant materials were ingested in trace amounts by carp. The volume of food items eaten in winter was usually less than amounts consumed in summer or during open water periods.

Extensive studies of food habits of carp in Indonesian ponds were performed by Vaas and Vaas (1959). They concluded that micro-crustaceans and chironomids were the predominate food eaten by carp. When these food organisms became scarce, algae were utilized and formed an important part of the food eaten. These carp were less than two years old.

Rehder (1959) found that plant material was the most consistent food eaten and comprised the bulk of the diet of carp from the Des Moines River in Iowa. Plant seeds also appeared in the diet especially when water levels were high. Insects comprised a relatively small amount of the food ingested. Most insects were larval midges of the family Chironomidae. Earthworms contributed heavily to the diet of carp captured from the waters of an inundated plain. Some of the food items appearing in the diet were related to the water level fluctuations. He concluded that carp preferred animal life over plant life when both food types were abundant in flooded areas.

Food items of carp from Lewis and Clark Lake, Missouri River, in order of volumetric importance, were organic detritus (61 percent), insects (19 percent), microcrustaceans (10 percent) and phytoplankton (9 percent) (Walburg and Nelson, 1966). Chironomids and cyclopoid copepods were the major animal items eaten. Diatoms comprised only 3 percent of the volume eaten. Lewis and Clark Lake carp were found to ingest more plant material than animal.

Jude (1968) found that there was a difference of food habits of carp captured from the open waters of the Mississippi River and those taken from a backwater slough. The diet of carp from the shallow habitat of the open river was largely composed of fingernail clams. Hexagenia constituted a significant portion of the diet of carp during June and July. Chironomids were found in fish from open river during every period of the investigation but were never important volumentrically. Vegetation only attained importance during May.

Chironomids comprised the greatest volume of the diet of carp from Honig's slough during May and June. Ostracods and cladocerans were numerically abundant in the food eaten by carp during the summer, but they composed only a minimal part of the amount consumed. The carp did not utilize Hyalella, even though these organisms were very abundant in the bottom fauna. Hyalella however was found in large numbers from the digestive tract of a carp taken from the open river in December, 1967.

From my study, the food items of carp from Clear Lake, Iowa, were mainly bottom organisms such as chironomids, caddisfly larvae, snails, fingernail clams and plants which live on the bottom. Microcrustaceans and algae were taken incidentally by carp but were not important as food items, although the percentages of occurrence of algae were high.

From the review of the studies of the food habits of carp, we may conclude that these fish are bottom feeders which utilize benthic organisms especially chironomids. Since Hyalella were abundant in the bottom, but were not utilized by carp (Jude, 1968), there is an indication that carp have an ability to select their food. The taste buds in the buccal cavity play a role in food selection. When food is scarce, carp utilized algae and microcrustaceans as a second choice.

SUMMARY

The application of the scale method to the older carp scales revealed some difficulties because of the presence of the false annuli which were recorded very often on the scales. The carp scales seemed to be sensitive enough to record any disturbances which caused cessation of growth. However the true annuli of carp scales can be detected from the following characteristic: the anastomosis of the circuli on both shoulder fields is followed by a wider space than the spacing of the circuli of the previous annual zone. This wide space in the anterior field can be detected by following the wide space from the shoulder area.

The opercle method gave results in which more confidence could be placed and required less time than the other methods for growth study. However the calculated length of one-year-old fish by using this method seemed to be longer than by using the scale method. Probably the growth of the opercle was fast in the first year and not proportional to the growth of the body.

The vertebrae method was very useful in checking the scale annuli and the opercle year marks. In older carp, the year marks of the vertebrae were dense on the edge but they could be counted under a binocular microscope.

The number of the year marks indicated on the vertebrae and opercle and annuli on the scale were the same, except on one fish.

The growth of carp in Clear Lake was fast the first two years and decreased thereafter. Although the growth of carp from Clear Lake in 1967 and 1968 was not as fast as the growth in 1951, it was still faster than in the reservoirs described by Walburg and Nelson (1966).

Carp of Clear Lake are bottom feeders which utilize benthic organisms, especially chironomids.

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